SMI BRC
WH Bryan Mining &
Geology Research Centre

DMQ Wrap-up – May 2017

Geochemistry

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AUSTRALIA

Geochemistry in the DMQ project

- DMQ was limited to GSQ and Chinova data – no new samples were collected or geochemical analyses performed;
- The available geochemistry data was not collected with research as a primary driver;
- Geochemical element suites were inconsistent (Cu, Au, + …..) and had variable detection limits;
- The sample digest and instrumental method is often not obvious. This influences how the data might be interpreted.

Interpretive products from geochemistry

- **Lithogeochemistry.**
  - Rock type (small samples, highly altered samples, EOH AC interface samples etc.);
  - Immobile trace elements: Sc, Nb, Zr, Cr, Th, Ce, Ti, Hf.
- **Alteration geochemistry.**
  - Will be influenced by protolith (mafic/felsic);
  - Style and intensity;
  - Major elements: K, Na and Al for GER diagrams, Fe.
- **Pathfinder elements.**
  - Ore elements are a good start;
  - Proterozoic IOCGs might have Cu, Au, U, Co, Ce, La, Ba, F, W, Mo, Bi, As, Cl and K associations.
- **Geochemical indices and discrimination plots.**

Mt Dore-Merlin & Starra Rock Geochemistry

- The surface samples are typically incomplete digests;

- Drilling data:
- Mt Dore (50,222 assays)
  - 74% of the drilling samples have major element data reported;
  - However, 94% of the major element determinations are derived from AR digests.
- Starra (107,233 assays)
  - 17% of the drilling samples have major element data reported;
  - However, 52% of the major element determinations are derived from AR digests.

- Drilling data were screened to select just those samples thought to represent total digests

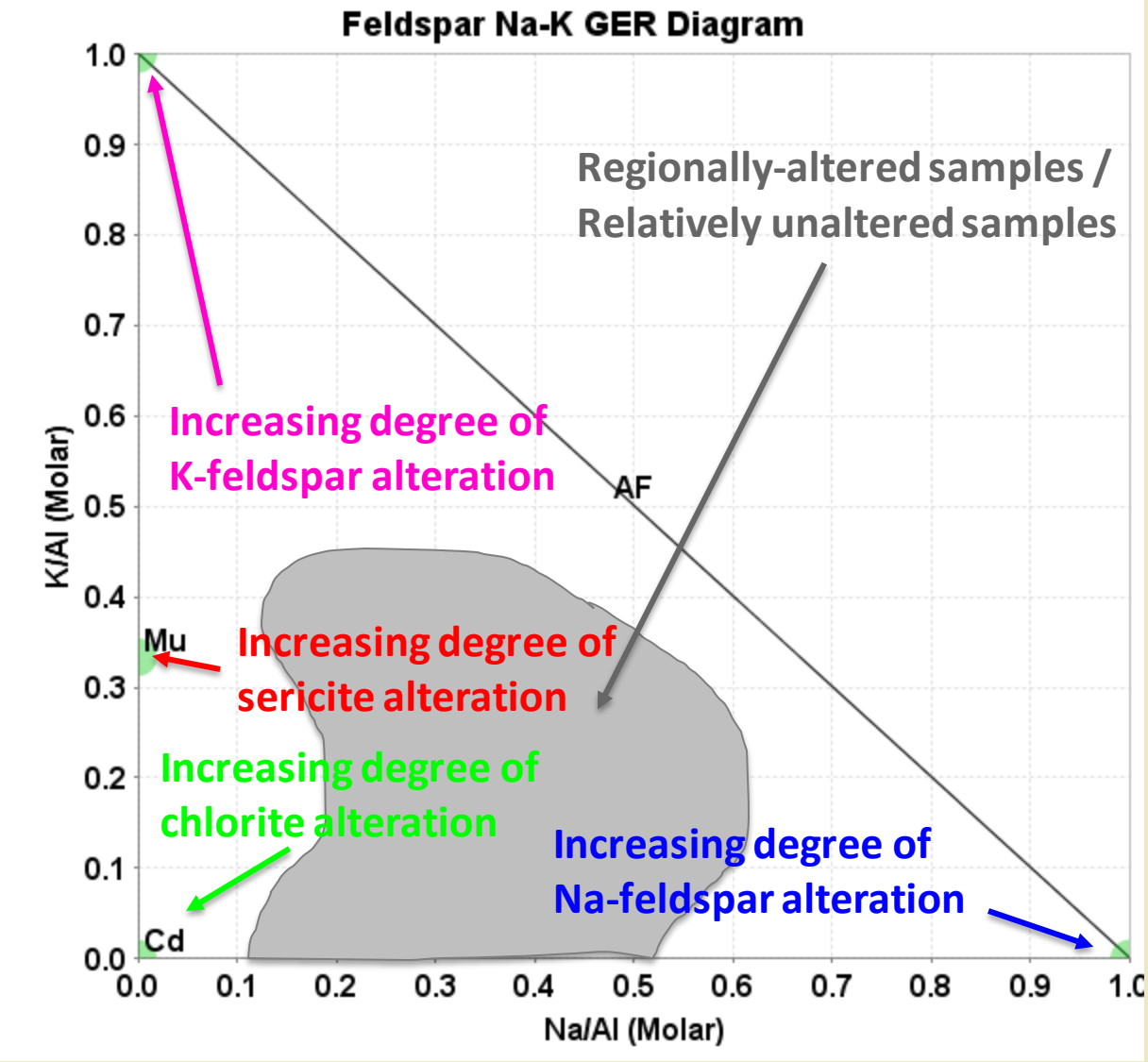
Alteration Geochemistry: Starra – Mt Dore

- Major elements, particularly K, Na and Al are considered essential for defining alteration style and intensity

- Sodic-calcic+iron alteration
  - Early, pre-mineralisaton fluid circulation;
  - Broadest & deepest in the system;
  - Deep circulation of high-salinity fluids, scavenging metals.
- Potassic-iron alteration
  - Typically more focussed than the sodic-calcic alteration;
  - Better preserved at shallow depths;
  - The Cu-Au mineralisation itself is better focussed still.

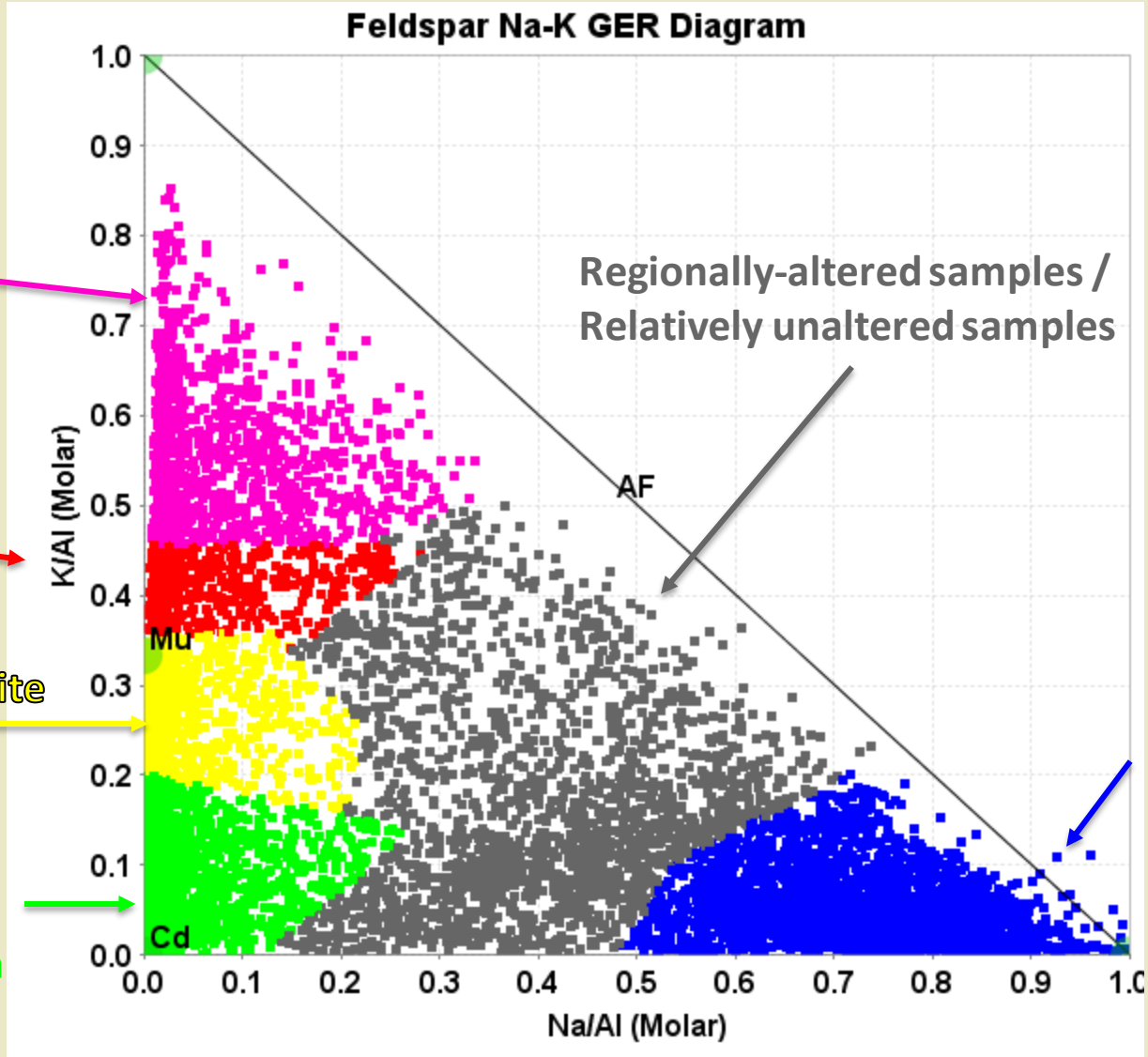
- In the Gawler Craton IOCG district, elements typically associated with IOCG mineralisation were found to be enriched in sericite-Fe oxide and chlorite-Fe oxide assemblages – determined using major element molar ratio geochemistry and spectral mineralogy (Fabris *et al*. 2013).

General Element Ratio Plots

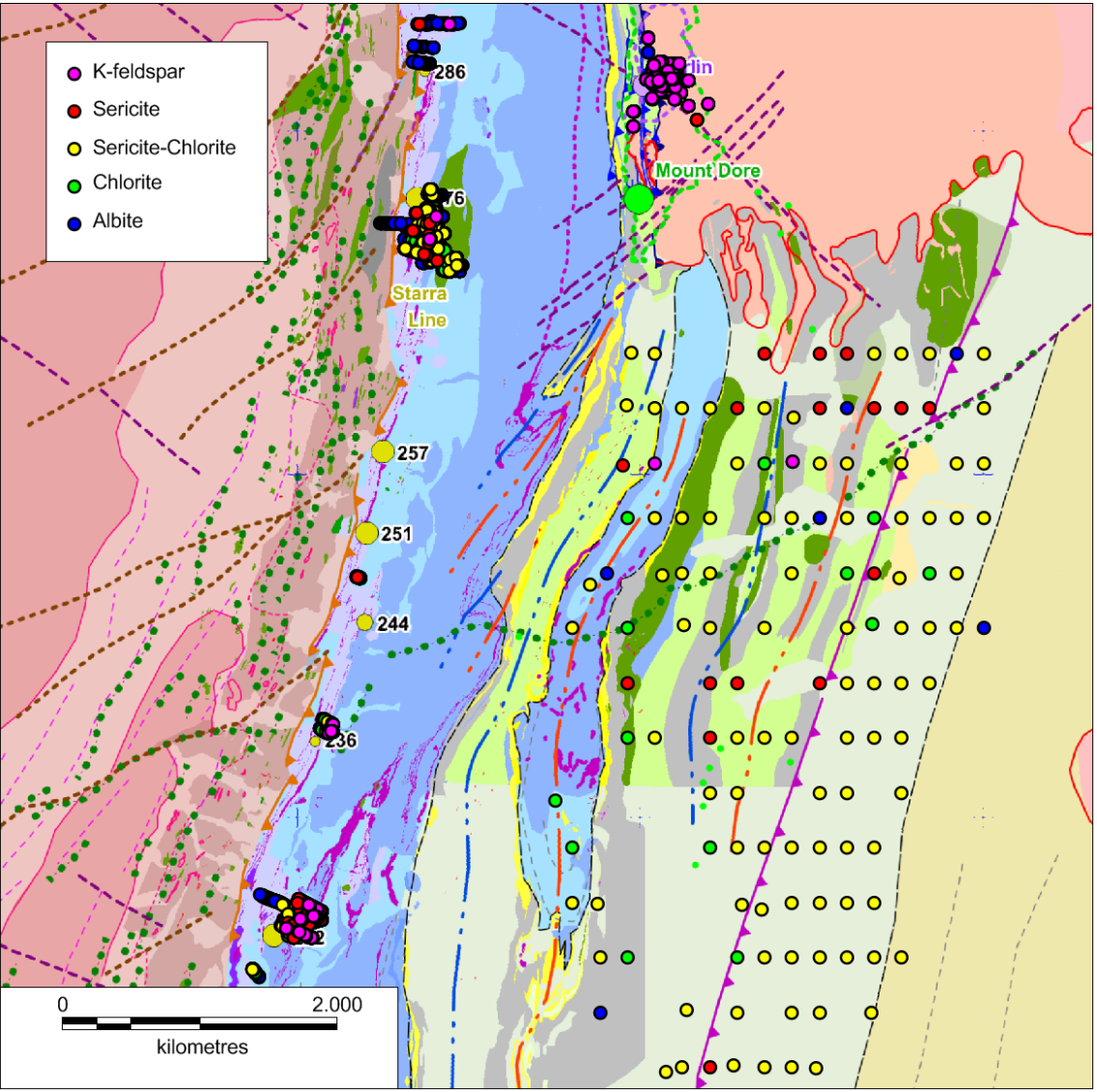


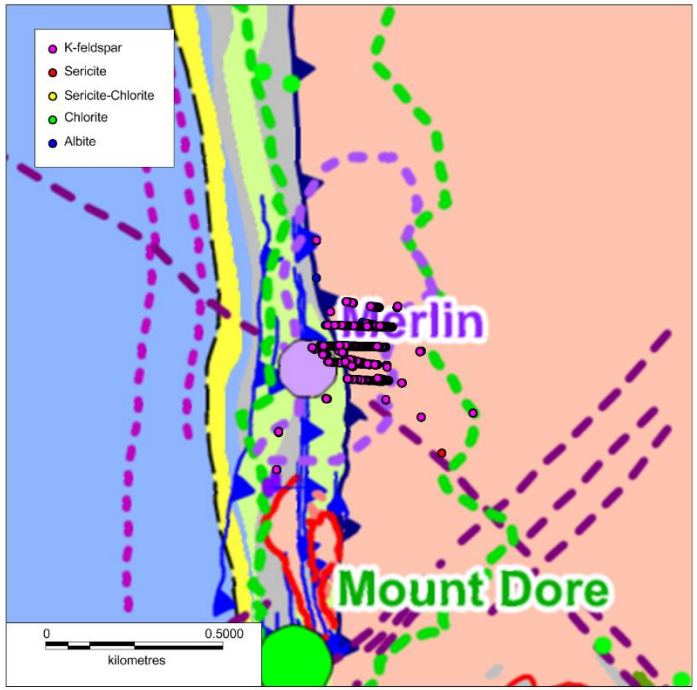
- Requires inputs of Na, K and Al
- Requires that these elements are fully recovered (XRF, 4-acid, fusion methods)
- Alteration fields will be different depending on protolith (mafic – felsic)

General Element Ratio Plots



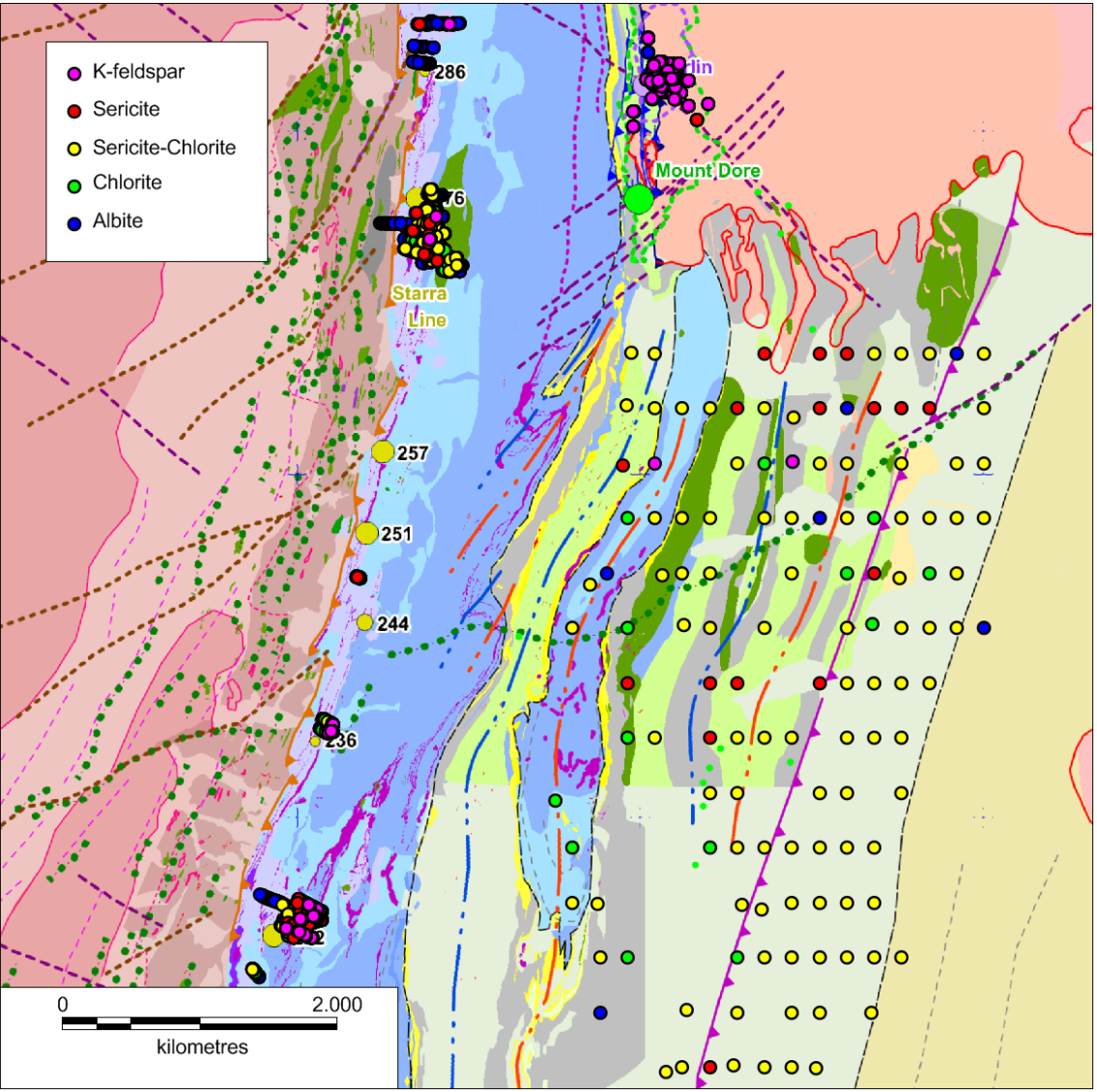
Mt Dore – Merlin – Starra Line

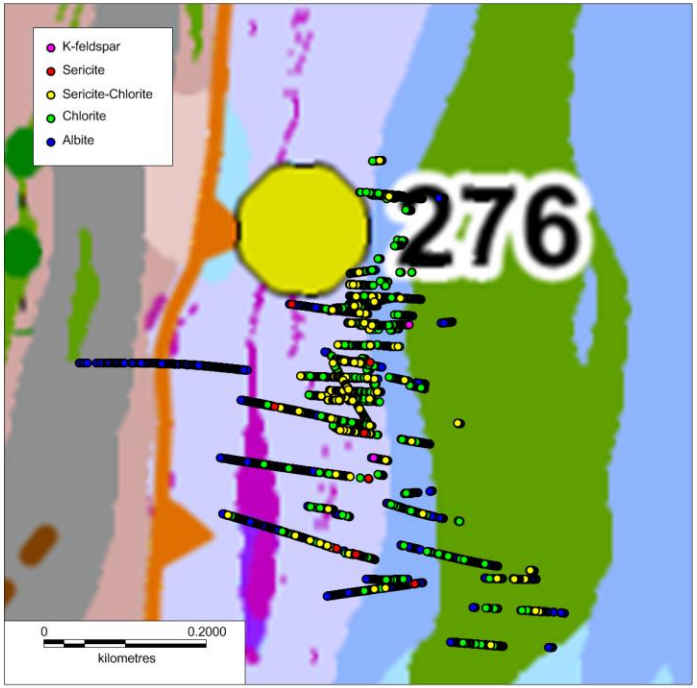




- Limited sampling at Merlin
- K-feldspar and sericite dominant alteration

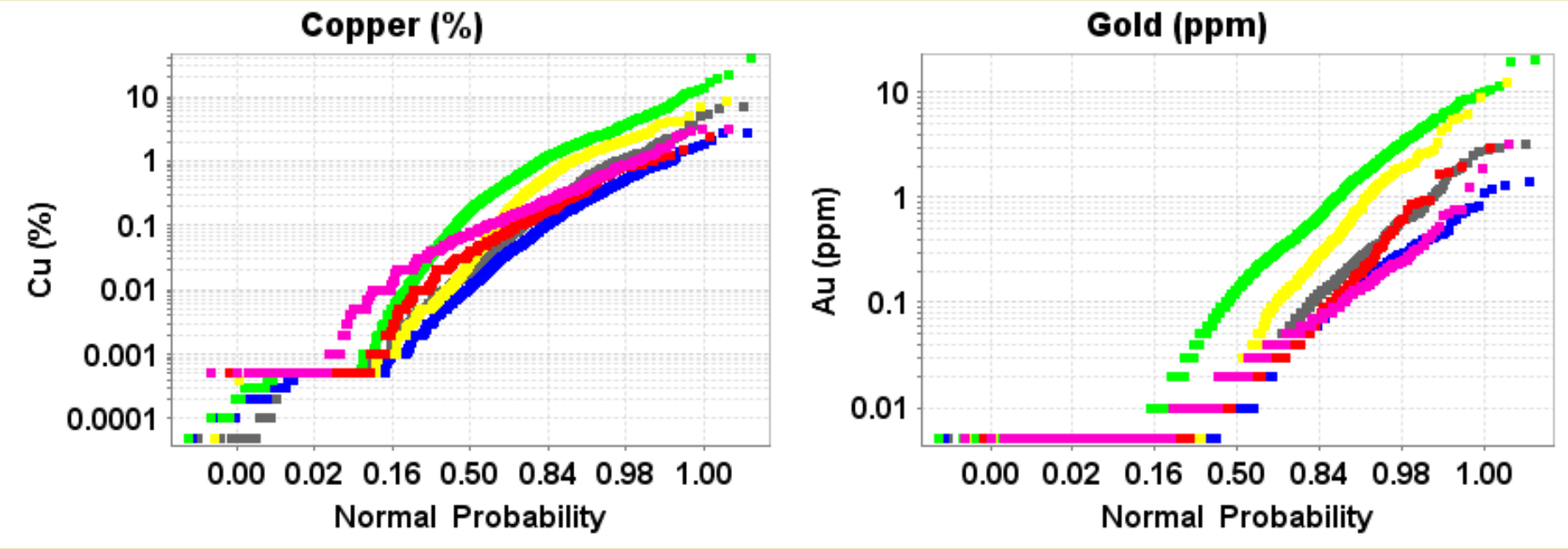
Mt Dore – Merlin – Starra Line





- Reasonable sample availability at Starra 276
- Mix of alteration types, but dominated by chlorite & chlorite-sericite

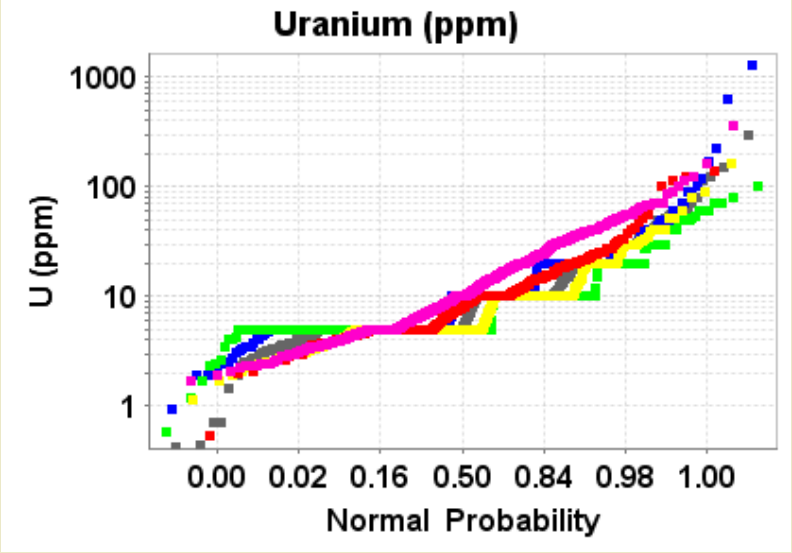
Copper & Gold – alteration assemblage

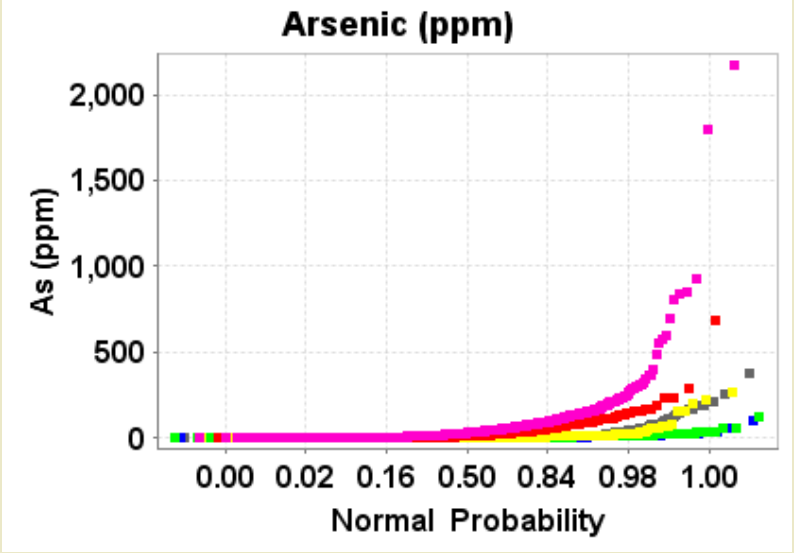


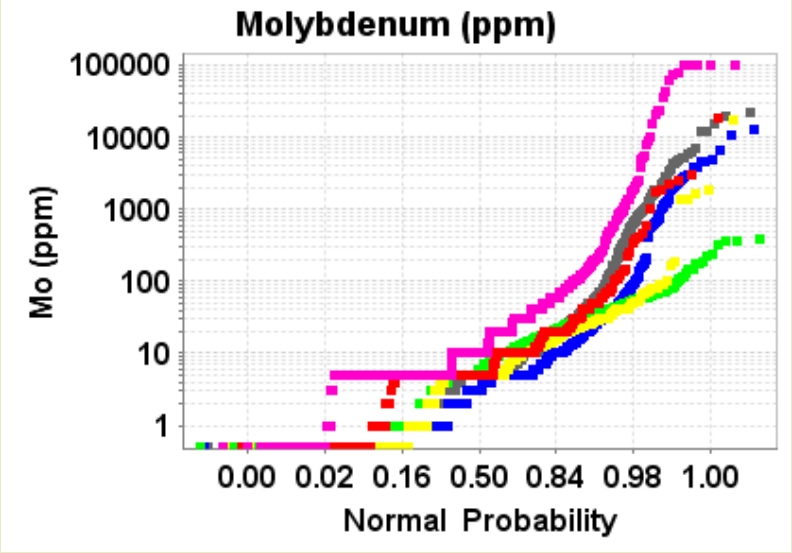
- K-feldspar
- Sericite
- Sericite-Chlorite
- Chlorite
- Albite
- Background

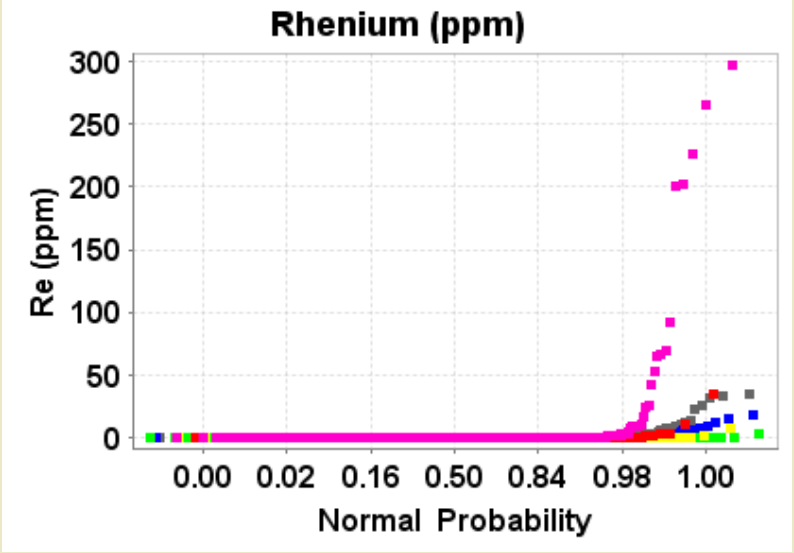
Those samples interpreted (from major element geochemistry) to have a sericite-chlorite or chlorite alteration assemblage are enriched in Cu and Au relative to other interpreted alteration assemblages.

U, As, Mo & Re – alteration assemblage

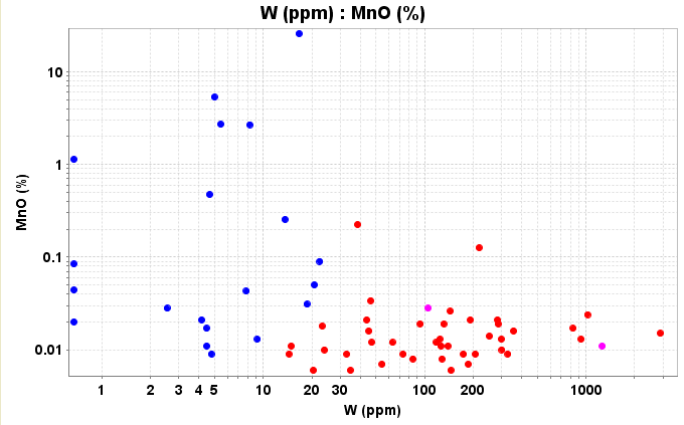


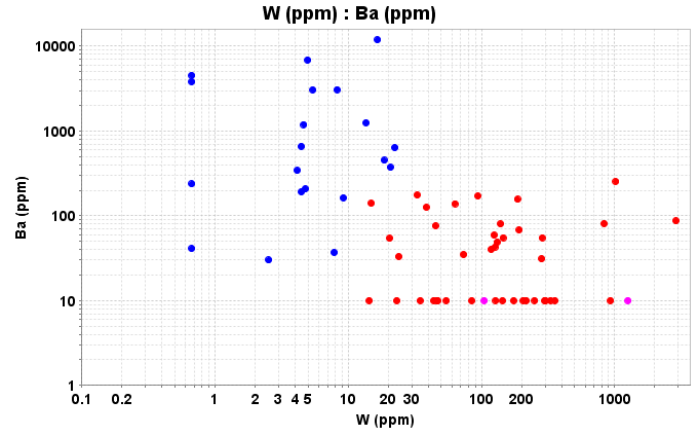


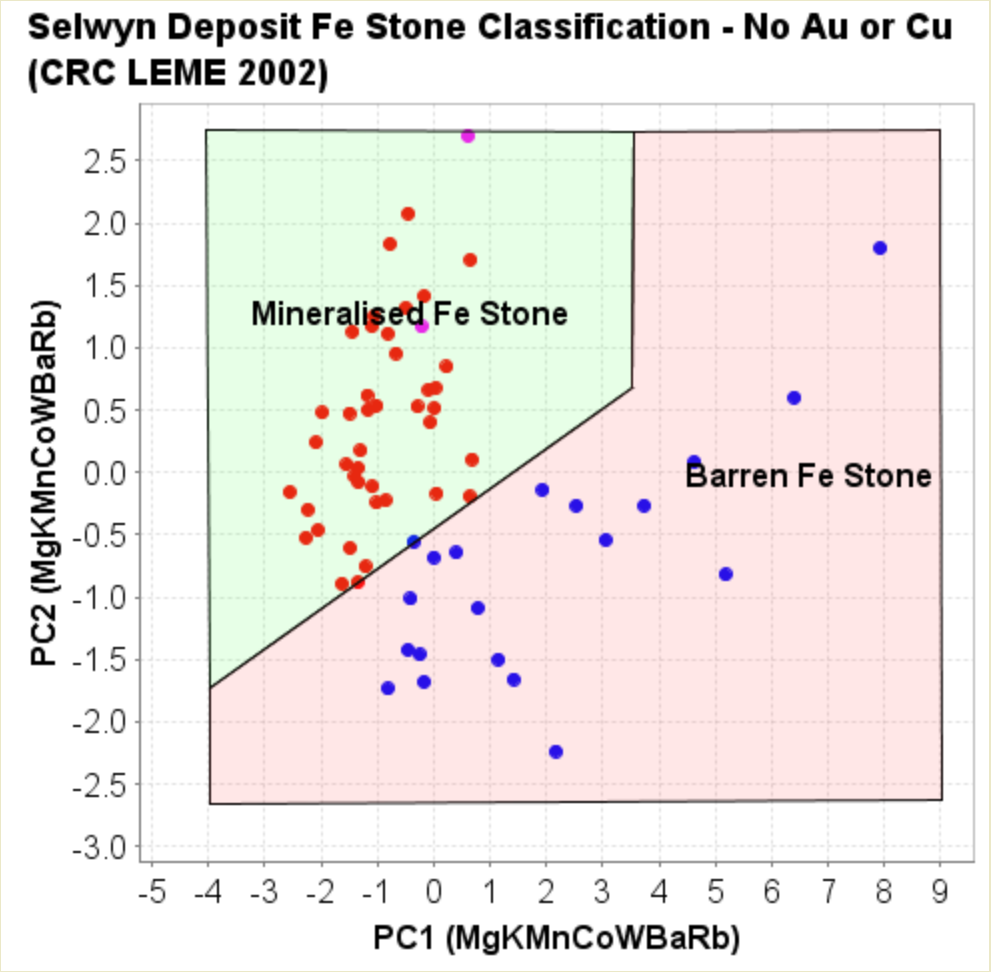




CRC-LEME OFR128 Selwyn Ironstones data (Starra 257 & 251) Bivariate plots & multivariate (PCA) plot (ioGAS software)

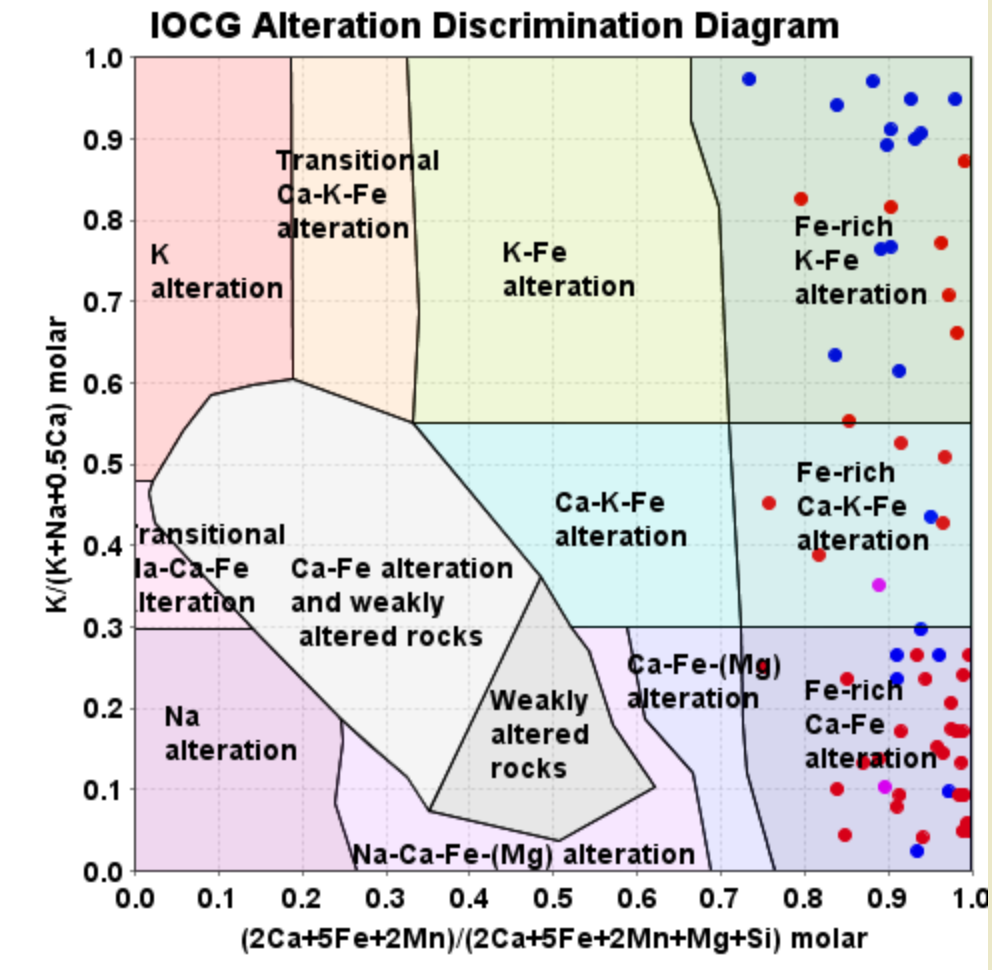






Wildman (2002)

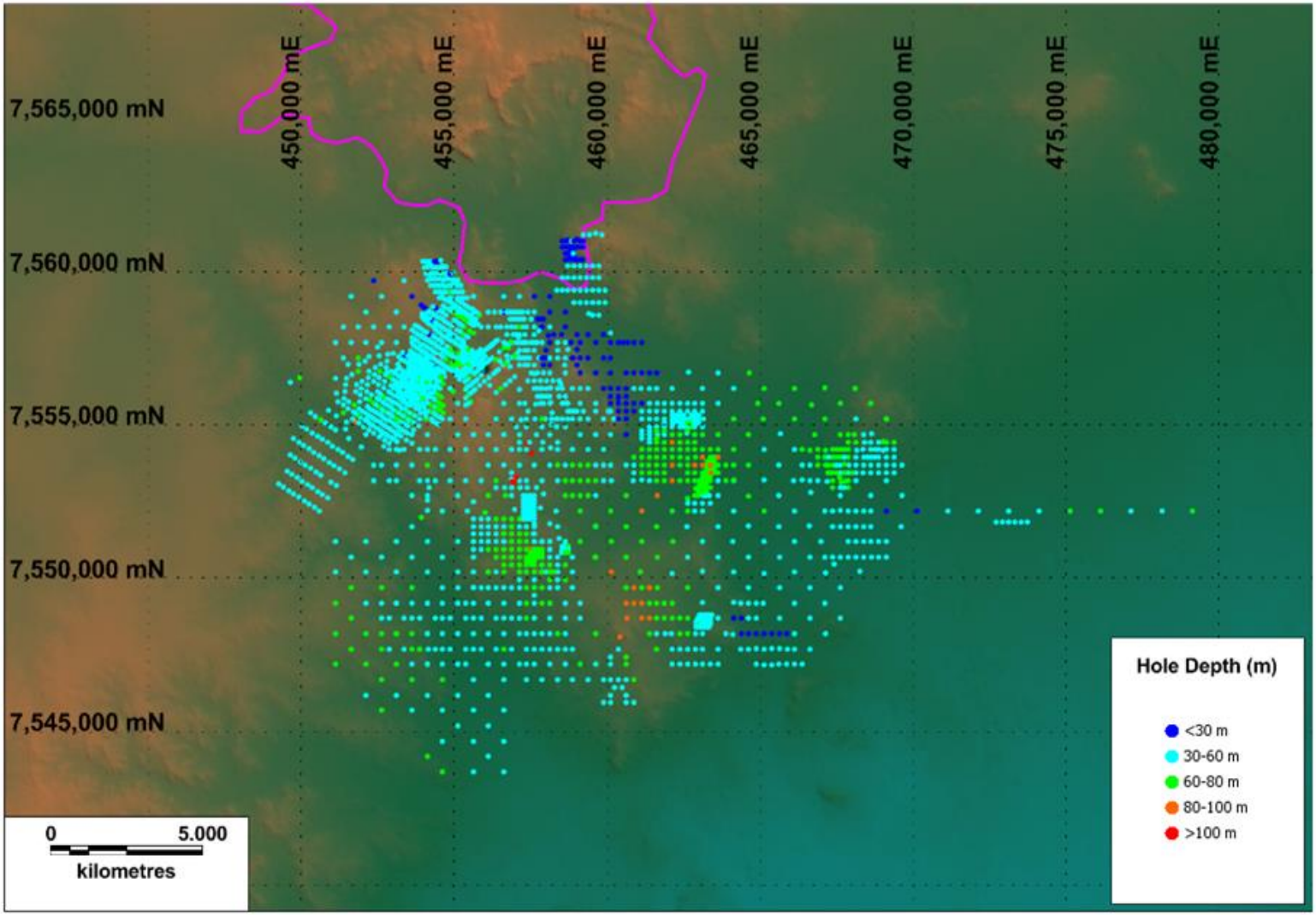
CRC-LEME OFR128 Selwyn Ironstones data (Starra 257 & 251) IOCG alteration discrimination diagram (ioGAS software)

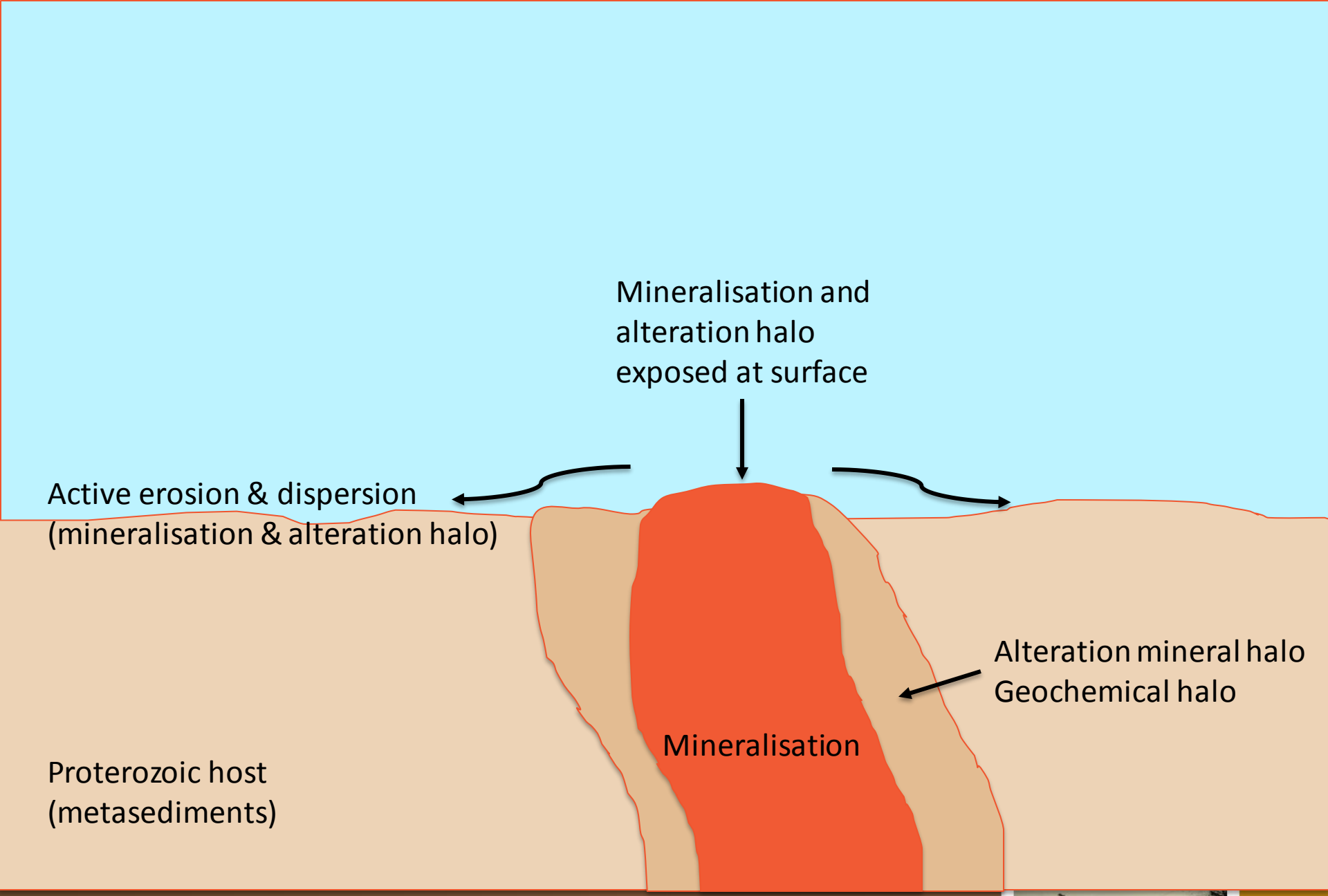


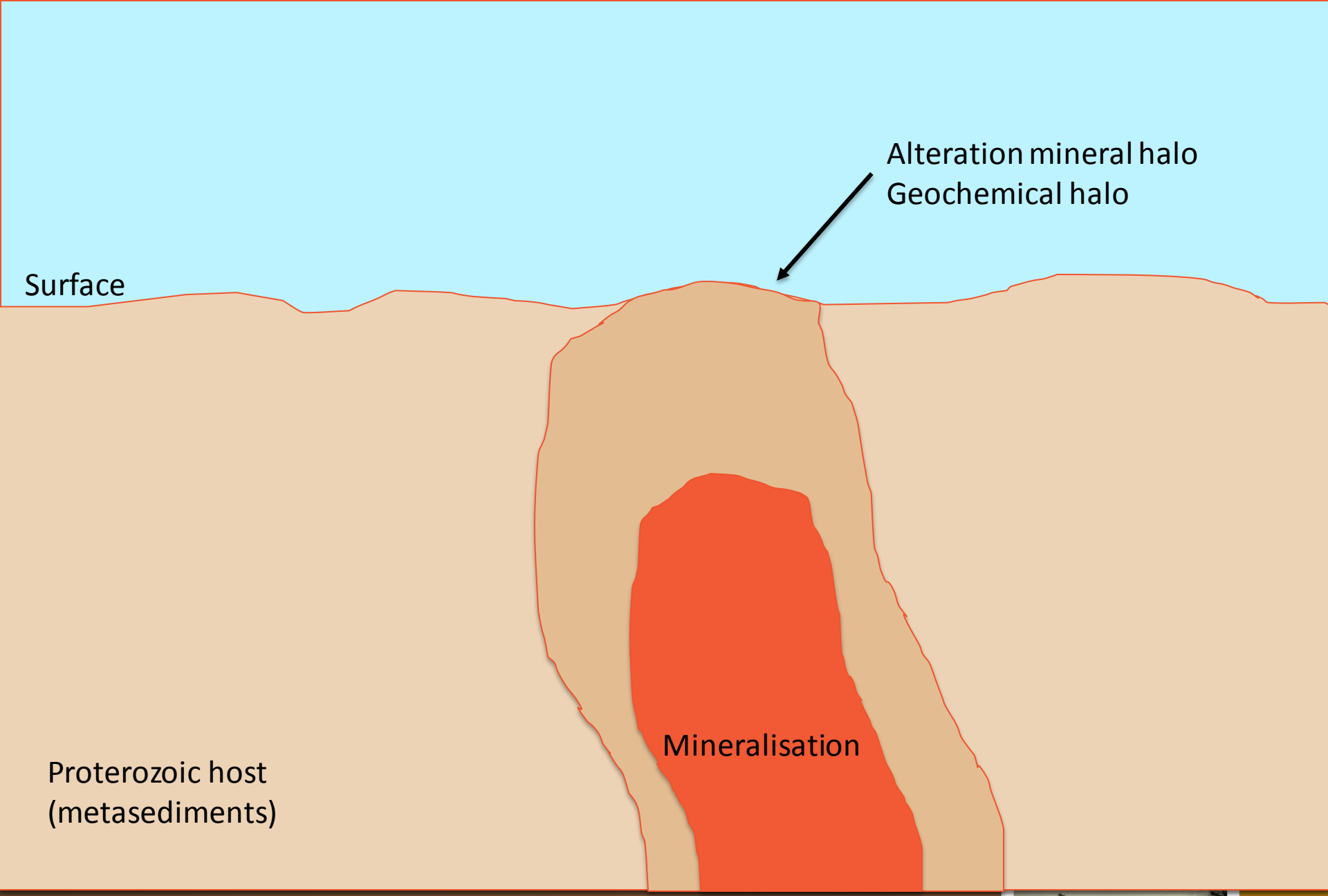
Montreuil *et al*. (2013)

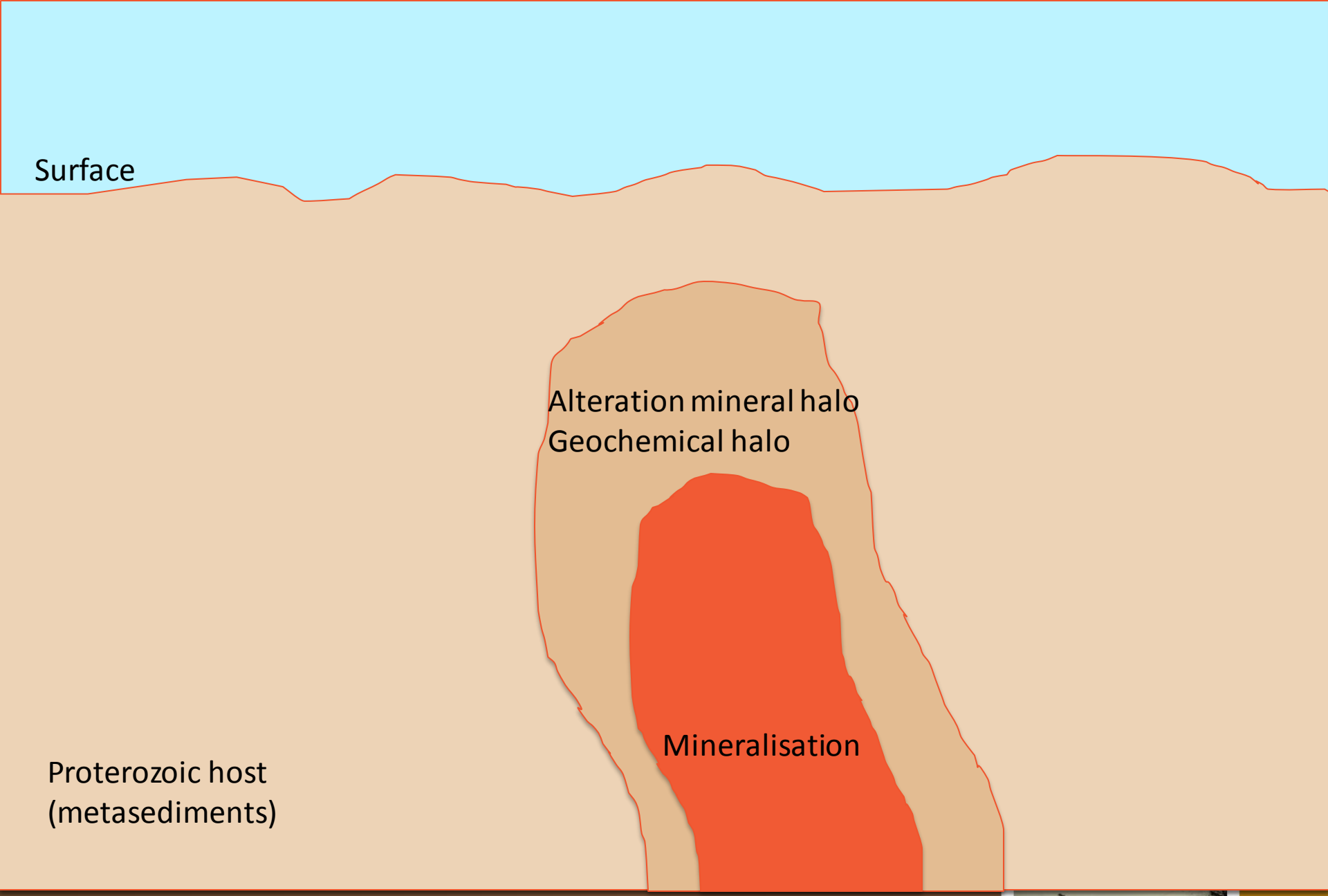
- Modified alteration index of Benavides *et al.* (2008), Central Andes: Ca, Na, CO_2, Si, Al, Fe, Mg. Correlates with Cu concentration. Improvement over K/Al and Na/Al ratios.
- IOCG prospectivity index of Fabris *et al.* (2013), Gawler Craton: Au, Ag, As, Ba, Bi, Ce, La, Mo, Sb, Se, Te, W. Values >0.8 correlate with significant IOCG occurrences.

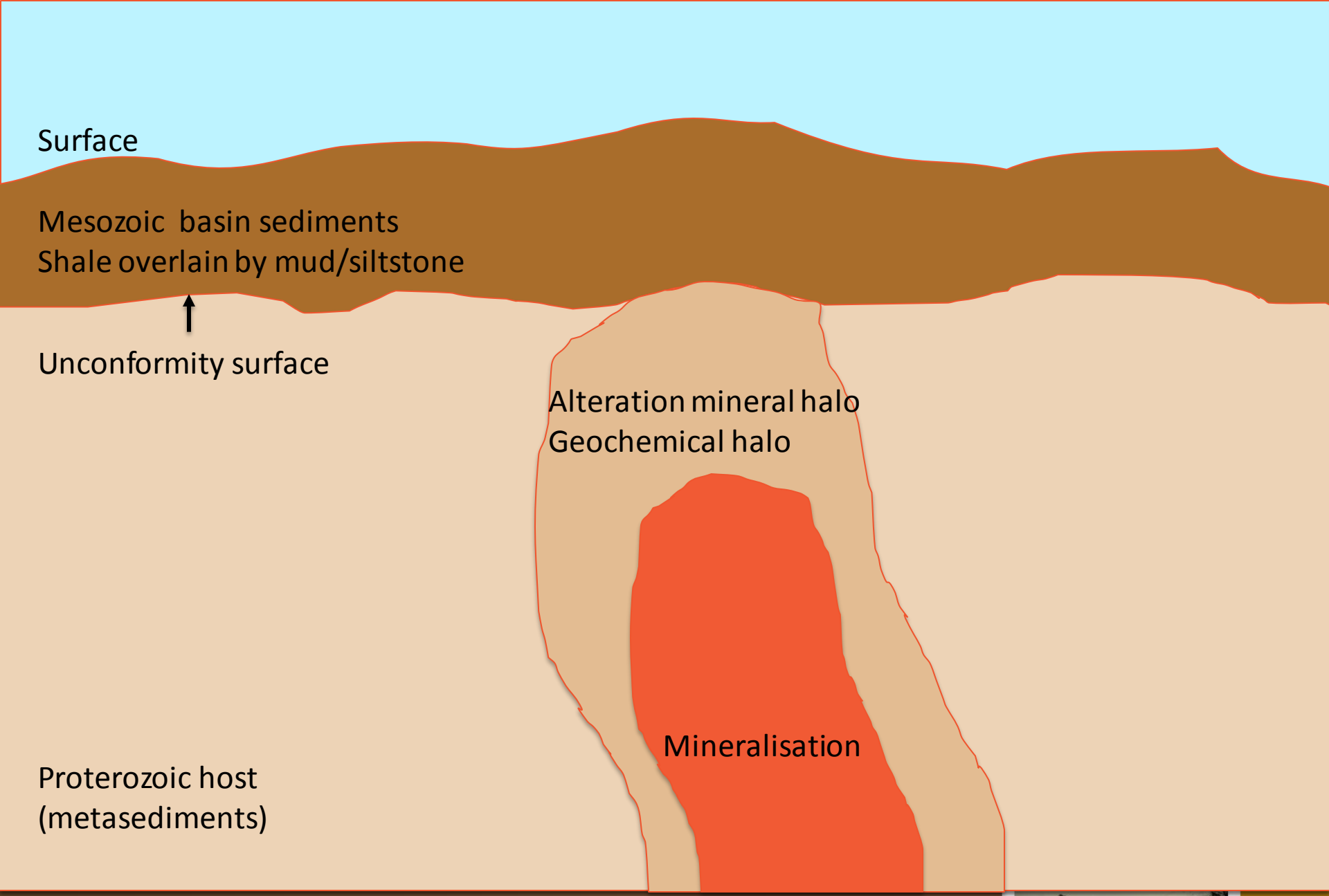
Mesozoic cover – south of Osborne



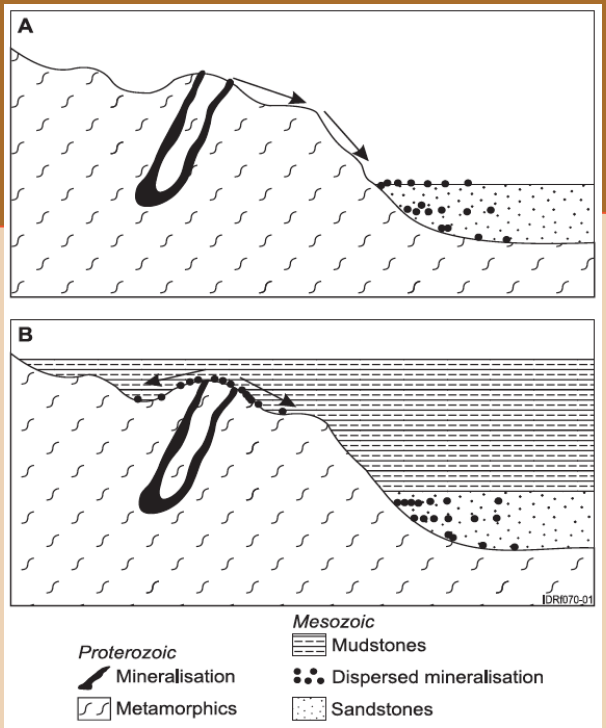

Mineralisation and
alteration halo
exposed at surface
Active erosion & dispersion
(mineralisation & alteration halo)
Alteration mineral halo
Geochemical halo
Mineralisation
Proterozoic host
(metasediments)

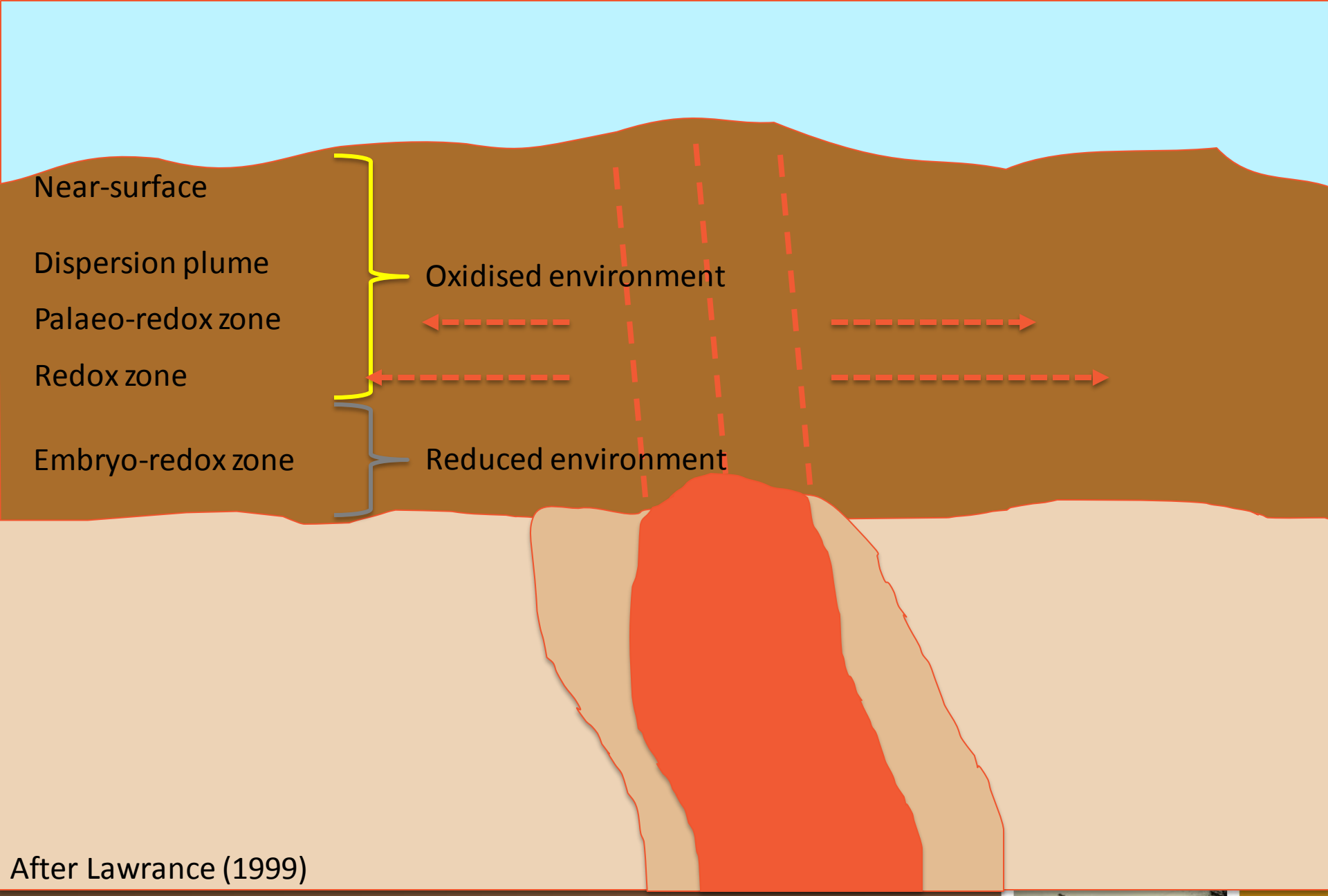

Alteration mineral halo
Geochemical halo
Surface
Mineralisation
Proterozoic host
(metasediments)


Surface
Alteration mineral halo
Geochemical halo
Mineralisation
Proterozoic host
(metasediments)


Surface
Mesozoic basin sediments
Shale overlain by mud/siltstone
Unconformity surface
Alteration mineral halo
Geochemical halo
Mineralisation
Proterozoic host
(metasediments)

Interface samples
(gravel samples at base of cover)
30-100m below surface





After Lawrance (1999)

Multi-element dispersion in cover over Osborne

Group	Cations							Oxides		Oxyanions			
Pathfinder	Au	Cu	Ag	Zn	Cd	Pb	Co	Fe	Mn	As	Bi	Se	Mo
Oxidised Environment													
Near-surface													
Dispersion plume													
Palaeo-redox													
Redox zone													
Reduced Environment													
Embryo-redox													

Key	High association	Moderate-high association	Moderate-low association	Weak association	No association

After Lawrance (1999)

Recommendations to explorers

- A lot of expense goes in to drilling. Drilling provides a sample. Multi-element geochemistry can help extract more value from drilling samples;
- Think about what you'd like from the geochemistry. Have a plan and get the element suite you need, using the digest and analysis you need, with the detection limits you need.

- Interface sampling
  - Assumes that a deposit was once exposed and eroded
- Cover sampling
  - Know where you are in the cover sequence – sample everything or objectively determine what you are sampling so that you can compare equivalent cover units
  - Potential for spectral mineralogy to assist

- No geochemical silver bullets that can reliably and consistently "see" deep – whether through host sequences and/or cover sequences